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Physics Educational Technology (PHET) Simulations in Teaching General Physics 1

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As stipulated in the "K to 12 Program" of the Department of Education, Philippines, the traditional way of teaching and learning should be transformed into electronic learning where ICT skills and technologies are introduced to the 21st-century learners, as well as 21st-century teachers. This paper tried to determine if teaching by utilizing Physics Education Technology (PhET) Simulations can impinge on the mastery of the least learned competencies in General Physics 1. It specifically analyzed the Proficiency level and Performance level in demonstrative applications in Physics. The current study also proposed an enhanced lesson plan exemplar that can be adopted by STEM teachers in teaching Physics. The descriptive method of research was employed in the study. During the investigation, there were 49 Grade 12 STEM students participated. The study concludes that PhET Simulation-Integrated instruction can improve the students' proficiency level on the least mastered competencies in General Physics 1. It also strengthened the claim that PhET Simulations can be a virtual laboratory for assessing students' performance on demonstrative applications. Further, utilizing and integrating PhET Simulations in delivering physics lessons can promote positive and engrossing learning experiences among learners.

Keywords: physics educational technology, PhET, proficiency level, demonstrative applications, lesson plan exemplar

Quality education in schools is becoming an issue all over the world. There are numerous questions concerning how existing education systems can be resolved and how quality education can be attained. Amidst the government's good guidelines and policies, most public education systems find the inapplicability of these to be implemented due to needs mismatched. These resulted to the decline in student learning, particularly in science education.

In 2017, Filipino high school students performed poorly in Science subjects as reflected in the results in the National Achievement Test (NAT). The DepEd reports that the NAT Mean Percentage Score (MPS) in Science is 41.35 percent (Dela Cruz, 2017).

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In 2003, the latest update on the Trends in International Mathematics and Science Study (TIMMS) results showed that the Philippines ranked 43rd out of 46 countries in 8th Grade Science The country also ranked 67th out of 140 countries in the quality of science education in the 2015-2016 Global Competitiveness Report of the World Economic Forum, and 79th out of 138 in the 2016-2017 data (as cited by Dela Cruz, 2017). With these alarming findings, Filipino science educators consider the nature of the subject matter as one of the significant factors which make Science and other related subjects challenging to learn – like Physics.

General Physics is also one of the specialized subjects in the Science, Technology, Engineering, and Mathematics (STEM) strand of the Senior High School curriculum of the K to 12 Program. It covers various topics that require students to reason, think critically, and solve problems using laws, principles, and mathematical equations. Despite its relevance, this subject remains the least favorite science subject among students, making it challenging to learn. This roots from the typical students' perception of understanding and learning Physics: Physics is difficult (Camaro and Nava, 2017), Physics is dependent on the language of Mathematics in communicating its qualitative and quantitative aspects (Reddy and Panacharoensawad, 2017; Aderonmu, 2014; Cretu, Garritano, and Schioppa, 2016), and Physics requires students to use a variety of methods of understanding and translate from one to the other, such as words, tables of numbers, graphs, equations, diagrams, maps ("Why Physics is Difficult", 2019).

Moreover, other reasons that could lead to student's downfall in Physics are teacher's traditional methods of teaching and learning (Wachira, 2014), lack of teaching and learning materials, and students' attitudes towards Physics (Akweya, 2014; Njiru and Karuku, 2015), lack of well-organized Physics laboratory equipment (Ng'Etich, 2014), lack of high mathematics background (Ng'Etich, 2014), lack of enthusiasm and interest to the subject matter (Mekonnen, 2014), and lack of qualified teachers to teach Physics ("Science Education Realities", 2014)

These problems have been experiencing by several teachers in SDO 1 Pangasinan. To certify, the researcher noted several least mastered competencies in General Physics 1 related to understanding concepts and principles, illustrating diagrams, interpreting graphs, and performing problem-solving. The analysis was based on the result of the quarterly examinations in the last three school years. Most of the least learned competencies were topics on Periodic Motion, Mechanical Waves, Fluids Mechanics, Temperature and Heat, and Laws of Thermodynamics.

At present, technology is becoming a necessity in the delivery of lessons. ICT integration has been implemented in today's classroom, where computer animations and interactive simulations are common. Numerous research studies have proven significant effects. Indeed, the integration of ICT on education shows a significant impact on the teaching and learning process. Teaching approaches such as Computer-Aided Instruction (CAI) have been seen to improve student performance, increase motivation and autonomy for learning, promote a positive attitude, and better performance in problem-solving (Suleman, Hussai, Din, and Iqbal, 2017; Tolbert, 2015;Williams, 2015; Egbodo, 2016).

With the mandate of the K to 12 Program, the traditional way of teaching and learning should be converted to electronic learning. Students are exposed to use the online world as an avenue for learning. With this, their ideas and knowledge will not be limited in a four-walled classroom, but instead, they can learn with the world.

One of the most promising strategies in planning a lesson is integrating computer simulations, an innovative and technological advance in the virtual classroom environment. It is a new concept that embraces traditional teaching advantages in the classroom and ICT-supported learning, including offline education and online learning.

Because of these, every teacher needs a carefully drawn lesson plan, irrespective of the training, experience, or competency. A lesson plan is required to assist the students in achieving the learning objectives. Having a lesson plan is exactly like having a complete and clear picture of how a learning process will occur and how students can grasp and retain what is being taught to them. Using a suitable lesson plan will provide guidance for the activities which are needed to be conducted in the classroom to reach the desired goal. This helps and makes the class hours interesting because the lessons are prepared in advance and the teacher knows how to jump from one topic to another. In this way, the teacher can also anticipate the questions that might be asked to him during the class ("Reasons Why Having a Lesson Plan is Important for a Teacher", 2018).

In this case, searching for a way to incorporate computer simulations into Physics lessons, the current study looks forward to using PhET simulations. The Physics Education Technology (PhET) is computer software that provides fun, free, interactive, and research-based science simulations. The simulations are written in Java, Flash or HTML, and can be run online or downloaded to the computer for offline activities. All simulations are open source. Multiple sponsors support the PhET project, enabling these resources to be free to all students and teachers (PhET Interactive Simulations, n.d).

Many studies on the integration of PhET simulations in teaching have indicated good results. It has a significant positive effect on student's performance and retention ability during instructional delivery, improve student's creativity, develop a positive attitude and interest in Physics, and leverage students in exploration and inquiry (Olorukooba, Sani, and Kazeem, 2016; Gunawan, Harjono, Sahidu, and Herayanti, 2017; Hursen and Asiksoy, 2015; Hassan, Saria, Guvena, and Sena, 2017; Chasteen, Moore, and Perkins, 2016).

In the Philippines, PhET is already introduced in the classroom and revealed successful results. It contributes to gaining satisfactory academic achievement, very useful in developing content knowledge and process skills and promoting more complicated goals and effective instructional materials (Potane and Bayeta, 2017; Siswanto, Gumilar, Yusiran, and Trisnowati, 2017; Bellingan, Buan, Calang, and Gabuya, 2018; Batuyong and Antonio, 2018).

Despite the idea that integrating and utilizing computer simulations in classroom instruction is not new, there are still limited related studies that were conducted about validating the effect of using PhET simulations on mastering the learning competencies

in Physics. Learning competencies are essential to master because it enables the learners to successfully apply the knowledge, skills, and abilities required to perform tasks in particular academics. It serves as a basis for skill standards that specify the level of knowledge, skills, and abilities necessary for learning success. Gosselin (2018) defines learning competencies as applied skills and knowledge that enable people to perform in professional, educational, and other life contexts. Learning competencies are combinations of attitudes, skills, and knowledge that students develop and apply for successful learning, living, and working (Gosselin, 2018).

For this reason, the primary goal of this study is to determine the effects of utilizing Physics Education Technology (PhET) Simulations on mastering the learning competencies in General Physics 1. Further, the study results provide a basis among STEM educators and curriculum developers on the potential of computer simulations in generating a virtual science learning environment that is fun, exciting, engaging, and interactive for every student.

Framework of the Study

Different theories of learning guided the preceding discussion on the teaching of General Physics 1 through PhET simulations. The integration of PhET Simulations has been significantly associated with pedagogical theories that support ICT integration in the classroom. Below are the theories on which this study is anchored:

Blended Learning Theory

It is a computer-mediated instructional strategy that leverages technology and focuses on the student-teacher relationship to enhance independence, engagement, and achievement (Akinbobola and Asagha, 2015; Aslam, 2015). It is also a form of learning facilitated by an effective combination of different delivery modes, models of teaching, and learning (Connection, 2014; Giarla, 2017). Besides, blended learning theory goes beyond classroom technology integration because students are expected to learn through online content delivery while having some control over their own learning time, place, path, and pace (Staker, 2015). According to Hinampas, Murillo, Tan, and Layosa (2018), this educational approach enables the learners to have better performance in Science by doing active participation. Li and Tang (2017) supported that blended learning can also impart ideas for developing new teaching methods to take advantage of standard technologies. It informs science educators about the latest technologies available for blended learning design, development, and implementation.

Collaborative Learning Theory

Collaborative learning uses a classroom organization where students work in groups to help each other learn. The learning environment is characterized by strong motivation and smooth interpersonal interactions (Ma, Yan, and Wang, 2018; Roselli, 2016). According to Adolphus and Omeodu (2016), using a collaborative learning approach in teaching and learning Physics can enhance students' achievement. This approach allows group learning, group projects, tasks, and assignments, facilitating collaborative learning, improving problem-solving abilities among the students, and promoting greater students' participation (Adolphus and Omeodu, 2016; Andam, Atteh, and

Denteh, 2016; Hossain & Tarmizi, 2014). Likewise, this approach is suitable in some instances as a learner has time to learn privately at a convenient pace. It can encourage the scaffolding technique, as there will be incremental knowledge acquisition on the learners' concept (Lawrence, 2015).

Constructivist Theory

According to Bruner (as mentioned by Ayaz and Sekerci, 2015), constructivist learning is an active learning process in which learners construct new ideas or concepts based upon their current/past knowledge. It stresses that teaching should always lead to boosting cognitive development. The instruction needs to be anchored on the learner's cognitive capabilities. Bruner recommended that using a combination of concrete, pictorial, and then symbolic activities would lead to more effective learning. Besides, this theory claims that learners must be exposed to various activities to promote students' collaboration in the classroom, which might reduce their misconceptions and improve their achievement. By grounding learning activities in an authentic, real-world context, constructivism stimulates, and engages students (Olusegun, 2015). According to Kola (2017), constructivism's theory correlates with authentic learning as a student-centered learning paradigm. It is highlighted that for effective physics learning; teachers must always consider the students' prior knowledge. Naade, Alamina, and Okwelle (2018) also suggested that through constructivism, learning becomes an active process where students are engaged in minds-on and hands-on and discoveries to discover and create knowledge themselves become independent problem solvers.

Experiential Learning Theory

According to Dewey (as cited by Johari, 2018), experiential learning refers to the knowledge which is gained through the discovery of new information during the application of prior knowledge. The individual typically initiates it out of necessity; thus, relevance to the learner's reality is established. One of the learning methods that is seen to facilitate achievement in physics is experiential learning. According to Suhandi and Yusup (2016), the influence of experiential learning using computer simulations can further improve the process skills and conceptual understanding in Science than the effect of experiential learning using traditional experiments. According to Cretu, Garritano, and Schioppa (2016), experiential learning is a philosophy and methodology where educators engage directly in motivating learners, and reflection is focused on improving knowledge and developing skills. Thus, the present study incorporates experiential learning, which focuses on providing the students with active learning experience through discovery learning.

Problem-based learning (PBL) approach

It is a learner-centered instructional approach in which students learn through solving unstructured problems. The PBL approach has its theoretical roots in Dewey's (as cited by Levin, 2014) ideas that teaching should focus on guiding a self-directed intentional inquiry of real-world issues. PBL approach can catalyze shifting beliefs by helping learners reflect on their ideas while obtaining new knowledge, engaging in problem-solving, critical thinking, collaboration, and decision-making (Levin, 2014; Lundeberg,

2015; Pierce, and Lange, 2014). According to Gewurtz, Coman, Dhillon, Jung, and Solomon, 2018), the PBL approach allows students to work in collaborative groups to identify what they need to learn to solve a problem. They engage in self-directed learning and then apply their new knowledge to the problem, reflect on what they learned, and evaluate the strategies employed. Teachers serve as the facilitator of the learning process rather than the source of knowledge. According to Masiong (2015), using the PBL approach can motivate and develop skills and enhance thinking through hands-on manipulation. Thus, the retention of concepts in the students' memory is observed. According to Goldstein (2016), this approach induces higher motivation and active students' active learning involvement. It can improve students' attitudes towards learning physics, reducing fear, and increasing their self-efficacy and enjoyment of learning.

Objectives

This study focused on utilizing PhET Simulation as an instructional material in delivering lessons in General Physics 1 among STEM students in Bayambang National High School, Bayambang, Pangasinan during the first semester of the school year 2019-2020. The specific objectives were as follows:

1) To determine the proficiency level in General Physics 1 of the students before and after utilizing PhET Simulations;
2) To test if there is a significant difference in the pretest and posttest scores of the students after utilizing PhET Simulations;
3) To determine the level of performance of the students in their demonstrative applications in General Physics 1; and
4) To propose an enhanced lesson plan exemplar in General Physics 1

METHOD

This research is a descriptive analysis of the utilization of l Physics Education Technology (PhET) Simulation as an instructional material in delivering lessons in General Physics 1 among STEM students. It involves an analysis of the least mastered competencies of the subjects under investigation. The study employed a quasi-experimental research design that exposed all subjects to the treatment. The comparison in this design comes from examining subjects' values on the outcome of interest before and after the exposure.

The study subjects were the 49 Grade 12 STEM students, where 20 (41%) are males, and 29 (59%) are females, enrolled as of the first semester for the school year 2019 to 2020 at Bayambang National High School, Bayambang, Pangasinan, Philippines. The samples were selected from one of the hetero-sections of Grade 12 STEM class, specifically the STEM – Exodus. During laboratory experiments, they were grouped into ten (10) groups where each group is comprised of fast learners, average learners, and slow learners formed.

The researcher developed a 50-item multiple-choice type of test. It was developed in a 60-30-10 scheme of difficulty level. The test coverage focused on the least mastered competencies from the three chapters in General Physics 1, as reflected in the SHS

Curriculum Guide. This includes Periodic Motion and Waves, Fluid Mechanics, and Thermodynamics.

The researcher administered a pre-test assessment before the conduct of the study. Then, a post-test was administered when all the selected lessons were met. During discussions, the researcher conducted laboratory experiments with PhET Simulations. The participants were also invited for Focus Group Discussions (FGD) to share their learning experiences after using PhET Simulations. It was in the form of a group interview where a question was posed for probing. The answers were adequately documented, recorded, and analyzed.

The data gathering period was from August to October 2019. Only one Physics teacher taught the class. The teacher only used PhET Simulation-Aided Instruction as a teaching intervention.

To determine how effective the PhET simulations were on improving the proficiency of the students in General Physics 1, test scores and mean percentages were used. To test if there was any significant difference in the students' pre-test and post-test scores, a t-test for dependent samples was used and processed through the IBM SPSS software package. The statistical test is set at a 0.05 level of significance. To determine the students' performance level on demonstrative applications, standard rubrics for Laboratory Experiments were used. The conduct of the laboratory experiments were rated based on the criteria set for conducting an experiment in the laboratory by Stevens and Levi (2005). Finally, to analyze the students' responses after inviting them in a Focus Group Discussion regarding PhET Simulations-Aided Instruction, a simple interview analysis was utilized.

FINDINGS AND DISCUSSION

Proficiency level in General Physics 1

Based on the results, it can be noted that the students performed poorly during their pre-test assessment and demonstrated the "Beginning" Level of Proficiency. This finding reveals that the students have very little background knowledge on the topics covered by the written test administered. This poor performance in pre-assessment is expected among students. Guskey and Mc Tighe (2018) claimed that the low performance in pre-test assessments is brought by students' preconceived notions, misunderstandings, misconceptions, and knowledge gaps.

In contrast, a level up performance on the proficiency level of the students can be noted in the post-test assessment. The students exhibited a proficient level associated with the effectiveness of PhET Simulation – Aided Instruction. This indicates that they could master the "least learned competencies proficiently" in General Physics 1.

The initiative to use PhET simulations in teaching lays its foundation on the theory of blended learning that is described as a computer-mediated instructional strategy that leverages technology and focuses on the student-teacher relationship to enhance independence, engagement, and achievement (Akinbobola and Asagha, 2015; Aslam, 2015). Hence, the current study supports the findings of Hinampas, et al. (2018) that

this educational approach enables the learners to perform better in Science. These findings are also mentioned by Li and Tang (2017) in their analysis that blended learning can also impart ideas for developing new ways of teaching and learning.

Furthermore, the Grade 12 STEM students also agreed that their enhanced proficiency in Physics could affect their improved skills in understanding and analyzing physics problems. Further, this result confirms the analysis that using computer simulations, such as PhET, promotes good performance in problem-solving (Williams, 2015) and encourages students' positive perception of problem-solving (Egbodo, 2016).

Significant Difference between Pretest and Posttest Mean Scores

The pretest and posttest mean scores represent the students' proficiency level before and after exposure to PhET Simulations discussion in General Physics 1.

When the mean scores were subjected to t-test analysis, the computed p-value is $p = 0.00$. The p-value is lower than the 0.05 level of significance. Therefore, the null hypothesis, which states that there is no significant difference between the mean scores in the pretest and posttest of the students after exposure to PhET Simulations Instruction, is rejected. This result shows that the mean scores of the students before and after the use of PhET Simulations was statistically significant, $p = 0.00$.

This implies that PhET Simulations can bring out a notable result. With PhET Simulation teaching, the teacher's approach in discussions and learning activities may have affected the process of effective mastery of learning competencies (Olorukooba et al., 2016); Hassan et al., 2017; Chasteen et al., 2016; Potane and Bayeta, 2017; Bellingan, et al., 2018; Batuyong and Antonio, 2018; Siswanto et al., 2017).

Level of Performance in Demonstrative Applications

In terms of their demonstrative applications, the students manifested an "Exemplary" level of performance. In all the laboratory experiments with PhET conducted by the students, a consistent "Exemplary" performance level was evident. The results indicate that students are very well-organized, very systematic, able to present data in ways that best facilitate understanding and interpretation, and their laboratory results are fully interpreted and compared with literature values.

In addition, the students' responses after asking them regarding their learning experience with PhET simulations also confirmed the exemplary performance manifested. They agreed that their exemplary level of performance could have a strong interest and positive attitude towards the lesson.

Undeniably, performing a task in groups promotes collaborative learning and experiential learning. This indicates that the exemplary performance can also be the influence of allowing the students to work collaboratively. This observation affirms the findings of Adolphus and Omeodu (2016); Andam, Atteh, and Denteh (2016); and Hossain and Tarmizi (2014) that the use of a collaborative learning approach in the teaching and learning Physics enhances students' achievement and promotes greater active participation. Likewise, allowing students to operate the computer simulations created effective experiential learning, which can be another factor of the students' exemplary performance. Suhandi and Yusup (2016) and Cretu et al. (2016) claimed

that experiential learning using computer simulations could further improve the process skills and conceptual understanding.

Proposed Enhanced Lesson Plan Exemplars in General Physics 1

The lesson plan exemplar was the main output of the study, which was crafted by taking into account the least learned competencies, demonstrative applications, and learning experience of the students in General Physics 1. One unique feature of the output was the integration of PhET Simulations in the development of the lessons. The comparison between the used lesson plans during the study's conduct and the proposed enhanced lesson plan exemplars are presented below:

Format and Style

The format of the used lesson plans and enhanced lesson plan exemplars were the same, and they were patterned using the Deped Order 42, s. 2016, also known as the "Policy Guidelines on Daily Lesson Preparation for the K to 12 Basic Education Program", where the format has six main parts and 14 sub-parts. The main parts include the *objectives*, *content*, *learning resources*, *procedure*, *remarks*, and *reflection*. The *lesson plans' objectives include content standards, performance standards, learning competencies*, and *specific learning outcomes*. The *learning resources* part is divided into *references* and *other learning resources*. The *warm-up* or the *review lesson, establishing the purpose of the lesson, presenting examples of the new lesson, discussing new concepts, practicing new skills, making generalizations and abstractions about the lesson, evaluating learning, and additional remediation activities* are found under the *procedures*.

However, there is a difference in terms of the style of how the lesson plans were prepared. The used lesson plans during the conduct of the study were constructed using the semi-detailed format, while the enhanced lesson exemplars were designed in a detailed format.

The adapted format and style of the proposed enhanced lesson exemplar supported Womack et al. (2015) that good lesson planning with detailed logical format impacts the teaching effectiveness. Ayres (2015) also mentioned that a well-designed lesson plan is a fundamental requirement for effective instruction. Cicek and Tok (2018) also strengthened that a detailed logical lesson plan must be established for effective classroom routine and time management.

Topics and Learning Competencies

The topics included in creating lesson exemplars were the lessons in General Physics 1 with "least mastered competencies." In this regard, the researcher outlined learning objectives and selected PhET simulations that fit the critical topics to address the low mastery of learning competencies in Physics for Senior High School.

Instructional Aid Used

The only instructional aid used in all the lesson plans prepared was PhET Simulations. The simulations are purposedly selected to fit with the desired learning competencies indicated in the lesson exemplars.

Another feature of the proposed lesson exemplar in General Physics 1 is verified by Castro (2017), where he stated that a content-based lesson plan is essential to design tasks and assessment methods. In addition, the studies of Gulbahar (2015), Liu (2016), and Thieman (2016) also verify that effective teaching via using computer technology is the new trend of future classrooms.

Presentation of the lesson

In the original lesson plans, only the teacher manipulates the PhET simulations in demonstrating examples and situations. But in the enhanced lesson plan exemplars, the students can operate the simulations as the teacher delivers the lesson. From this, the teaching-learning process becomes student-centered and constructivist in approach. The discussion is more interactive and interesting among students.

Conducting Assessment

In conducting the assessment, the formative test prepared in the lesson plans were aligned with the intended learning competencies. This feature was applied in both lesson plans to ensure effective assessment of learning.

CONCLUSIONS

Based on the findings of this study, the following conclusions are drawn:
1. PhET Simulation-Integrated instruction in teaching General Physics 1 could improve the students' proficiency level on the least mastered competencies in this learning area.
2. Teaching with PhET simulations could affect a student's achievement in Physics.
3. PhET Simulations could be used as a virtual laboratory on assessing the level of performance on students' demonstrative applications during laboratory experiments. It can be a solution to address the lack of laboratory rooms and equipment in the country.
4. Preparing a lesson is a fundamental requirement for effective instruction. A well-designed lesson plan that utilizes technology and promotes an engaging learning experience among the students is more effective. Lesson exemplars with PhET simulations can impact student's performance, attitude, and motivation

RECOMMENDATIONS

In the light of integrating PhET simulations in teaching lessons in General Physics 1, and the conclusions drawn from this research, the following are recommended:
1. The findings of this study can be used by Physics teachers and other STEM teachers handling other branches of Science in designing classroom activities and implementing a digital approach in teaching to improve students' proficiency in mastering learning competencies effectively.
2. Physics teachers may need to revisit the learning competencies in General Physics 1 that are identified as least mastered and look for innovative teaching approaches to improve them. This study suggests integrating computer simulations and virtual laboratories with proper utilization and monitoring in Physics discussions
3. It is highly suggested among Physics teachers and other Science Educators to design and develop PhET Simulations-Integrated laboratory experiments to address the

demand for ICT Integration in education. It is encouraged among science specialists and trainers to initiate training/workshops relevant to the utilization and integration of PhET Simulations in administering laboratory experiments and practical applications.

4. This study also encourages teachers to handle General Physics 1 to utilize the proposed enhanced exemplars to stimulate the students' interest, curiosity, positive attitude, and motivation to learn Physics. Given this point, it is recommended among Physics teachers to search for more specific topics in Physics that are usually boring and difficult and try to prepare lesson plans with PhET simulations.

5. Similar research can be conducted to integrate other computer simulations and virtual laboratories, like PhET, and make a comparative analysis. Further, parallel studies can also be undertaken, highlighting qualitative research on utilizing different computer simulations.

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